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MYLOSTOMID DENTITION.

By C. R. Eastman.

With One Plate.

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No. 7. — *Mylostomid Dentition.* By C. R. Eastman.

The reconstruction of the Mylostomid type of dentition acquires significance through its relevancy to the larger question of the affinities of Arthrodires. Nature has not disclosed to us by direct evidence the manner in which upper and lower dental plates of Mylostomids functioned against one another during life. The disposition of the various parts must therefore be determined by indirect means, such as by observing evidence of co-adaptation, mutual contact and wear, and, so far as may be, through analogy with related forms. In reality the problem is a simple one, devoid of mystery and intricacy, and requiring little mechanical ingenuity for its solution and complete verification. Of trivial intrinsic importance, its solution promises enlightenment as to the relations of the perplexing group of Arthrodires. A matter of minor interest in itself, it determines consequences of real magnitude, and hence is worthy of thoughtful consideration. It is proposed in the following pages to examine into the general nature of the problem, the different solutions that have been proposed for it, and some of the consequences depending thereon.

The limiting conditions of the problem may be stated first. Mylostomids are known upon the evidence of two fairly well-preserved skeletons to be Arthrodiran fishes essentially like Dinichthys, except that their dentition is adapted for crushing instead of cutting. The two specimens referred to are the only ones thus far discovered which present us with the disarranged but nearly complete dentition of single individuals. The fact that in each case the dental elements are known positively to have belonged to a single individual not only facilitates their reconstruction, but furnishes a scale of relative proportions which may be presumed to hold constant throughout the species. Thus provided with a standard of comparison, we may select from a sufficiently large assortment of detached plates the necessary components of a complete dentition, all of whose parts shall be proportionate with respect to one another, and shall have precisely the same conformation as those known to have been associated in a single mouth. Or, given a detached mandible of the same configuration as those found in natural assemblage with other parts,

the size of the upper dental plates which must have accompanied it during life can be predicted with entire accuracy.

Experience having shown that all of the dissociated dental elements now known, upper and lower, exhibit among themselves practically uniform dimensions and uniform conformation, one is entitled to conclude therefrom that they represent average-sized individuals, and that the elements were arranged after an invariable pattern. For, supposing their disposition to have been inconstant, we should be at a loss to account for their marked regularity of form and proportion, and similar indications of wear. Hence any theoretical reconstruction of the dentition, whether based upon detached specimens or upon the evidence of naturally associated parts, must satisfy the test of totality. It must apply universally, not only to such plates as are known to have belonged to a single individual, but to all those that have been found in the detached condition as well; it must be compatible with all their essential features, and be negatived by none of them.

It may be that only one, or more than one theoretical reconstruction of the dentition is competent to explain all the observed facts. As between two rival hypotheses, that one may be regarded as the more plausible which is mechanically simple, free from anomalous suppositions, and in harmony with analogy. An hypothesis which is mechanically complicated, presupposes anomalous conditions, and violates analogy, is less worthy of credence. For in so far as it depends upon the assumption of the unique, of something for which nature affords no parallel, it becomes improbable; and the improbable is always to be distrusted. Speaking broadly, any hypothesis whatsoever has the elements of trustworthiness, provided it can be shown to agree with a number of diverse facts. The greater number of diverse facts with which it agrees, the more completely can it be verified. When many circumstances point toward a single conclusion, the chances of that conclusion being correct are enormously increased with each additional favoring circumstance. They might even be supposed to increase in geometrical rather than in arithmetical ratio. Finally, an hypothesis that is found to agree entirely with observed facts cannot but be believed to be true. It will be instructive to inquire how far either of the two extant interpretations of Mylostomid dentition are in accordance with observed facts.

Newberry's Views. — Our earliest information regarding the Mylostomid type of dentition is due to the zeal and acumen of Professor J. S. Newberry, who described the constituent elements of the type species,

M. variabile, and also founded a second species, *M. terrelli*, upon the evidence of a solitary mandibular plate. He noted the general correspondence between the Mylostomid and Dinichthyid type of mandible, and observed that the former occurred together with two distinct varieties of "flattened tabular dental plates . . . exhibiting the same microscopic structure," which were properly referred to the upper dentition of the same species. He made no effectual attempt, however, to work out the arrangement of the pavement teeth, merely observing that their "sides are straight or bevelled, apparently for co-adaptation, and by this character favor the conclusion that the dentition consisted of many pairs of plates, constituting a tesselated pavement; the crowns of the teeth below being convex, those above concave."[1] The front margin of the mandibular plates was also considered by this author to show evidence of co-adaptation with other dental structures; and in order to satisfy the hypothetical requirements thus created, a pair of "premandibular" elements was not only postulated by him, but two specimens figured in his monograph[2] were actually referred to this position, albeit with some reservation. We will return later on to a discussion of these so-called "premandibular" plates, under a separate heading.

Newberry's investigations of Mylostoma served to acquaint us in all, as he supposed, with four pairs of dental structure, one of which was correctly identified as belonging to the lower, and two to the upper jaw, while the position of the fourth was acknowledged to be uncertain. His reasons for referring these various pairs to a single species are that they were found to occur together, and to exhibit identical structure and surface markings. The circumstances of their discovery are not related in detail, but it is significant that all specimens of Mylostoma known to Newberry, excepting the type of *M. terrelli*, were obtained by one collector from a single horizon and locality, namely, the Cleveland shale of Sheffield, Ohio. Newberry's suggestion that several pairs of plates besides these four took part in the complete dentition, and that the upper series formed a tesselated pavement, shows that he had only a vague and illusory idea of their arrangement. He even confused the right and left mandibular plates. His work was essentially that of a pioneer, and as such is praiseworthy, although necessarily imperfect. It was at Dr. Theodore Gill's suggestion that he undertook the first comparisons between the dentition of Arthrodires and Dipnoans, the

[1] Newberry, J. S., The Palaeozoic Fishes of North America. Monogr. U. S. G. S., 16 (1889), p. 166.

[2] *Ibid.*, p. 161, 165, Plate 16, Fig. 4.

former's ideas as to the relations of Homosteus having been published as early as 1872.

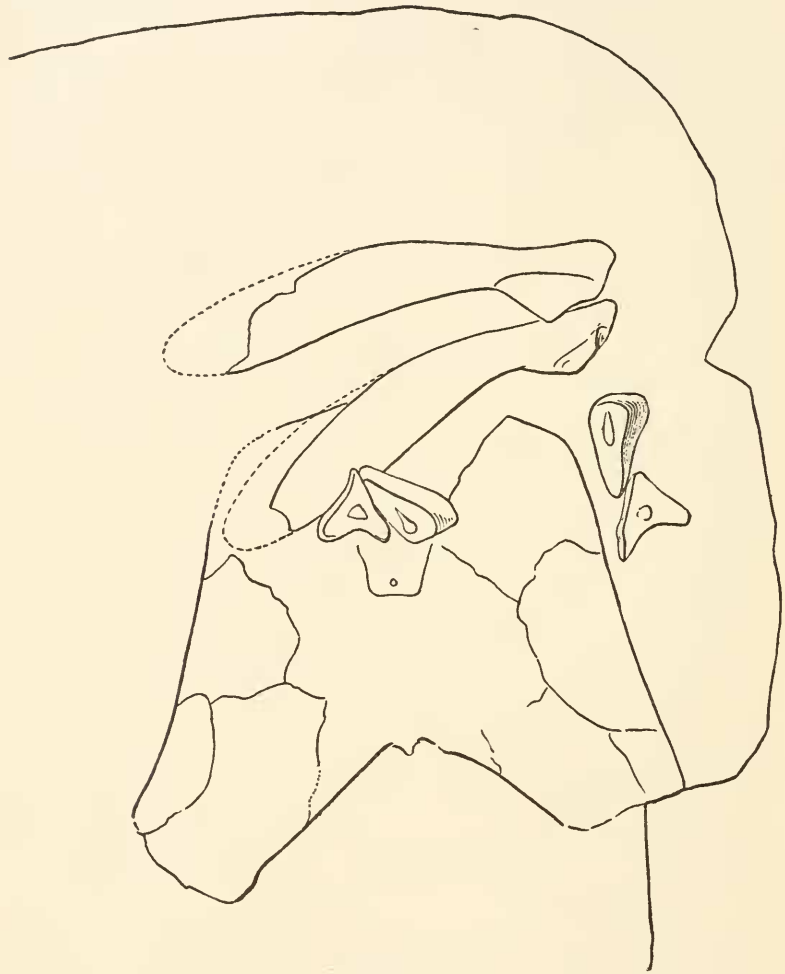

FIGURE *A*.

Outline sketch showing the position in which the constituent parts of the dentition were embedded with respect to the headshield in the block of shale containing the single individual of *Mylostoma variabile* juv. Museum Comp. Zoöl. (Cat. 1490); Amer. Mus. Nat. Hist. (Cat. 7526). × ⅓. (After Dean.)

DEAN'S INTERPRETATION. — To Professor Bashford Dean belongs the credit of having attempted the first serious and thorough-going restoration

of the dental apparatus of Mylostoma, his interest in the problem having been aroused by the discovery of a well-preserved skeleton of *M. variabile*, the various parts of which obviously belonged to a single individual. This specimen presented for examination the flattened headshield, some half-dozen plates of the abdominal armor, both mandibles, and two pairs of crushing dental plates, all embedded in close proximity to one another in a single block of shale. There were no indications, however, of the presence of a fourth pair of dental elements, corresponding to the so-called "premandibular teeth" of Newberry, and these latter do not enter into Dean's reconstruction.

As will be seen from Figure *A*, which is copied from Dean, the two mandibular rami were found lying nearly parallel to each other in close

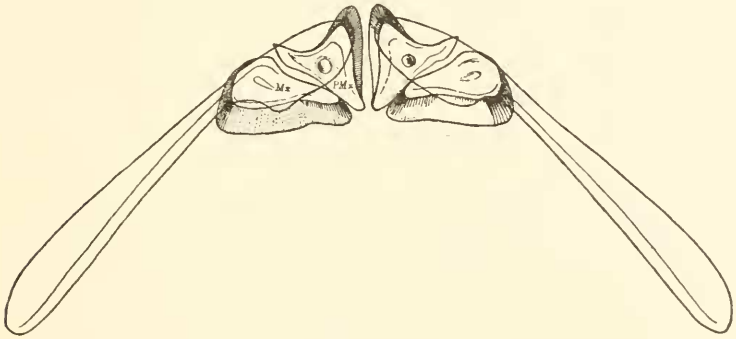

FIGURE *B*.

Restoration of the complete dentition of Mylostoma, based upon the single individual of *M. variabile* shown in Figure *A*. The length of the mandibular dental plate is slightly exaggerated in the outline here shown. × ⅓. (After Dean).

proximity to the headshield, and at no great distance from the separated halves of the palatal dentition. The two plates interpreted by Dean as belonging to the right-hand side of the palate are in direct apposition with each other, their contact edges being in remarkably close adjustment. These circumstances, the fact that the two right-hand palatal plates remain together while the corresponding left-hand plates have become separated, and the fact that their opposed edges show almost perfect co-adaptation, are held by Dean to point irresistibly to the conclusion that the elements in question have preserved their natural arrangement with respect to each other.[1] It is not demonstrated by the author, but merely considered as extremely probable that

[1] Dean, B., Palaeontological Notes. Mem. N. Y. Acad. Sci., 1901, **2**, p. 104.

the relations of these plates have not been disturbed; and this inference is made by him the determining factor of his restoration (Fig. *B*), the starting-point of his theory of rotary jaw-movements, and the key-note to a novel interpretation of Arthrodires. One perceives, accordingly, that extremely weighty conclusions depend upon Dean's initial assumption, the truth or error of which requires to be demonstrated. Sufficient reason for distrusting its correctness is found in the improbability of the conclusions resting upon it, the more important of which are contrary to analogy. We may therefore profitably inquire into the reasonableness of the author's initial assumption, and ascertain, if possible, to what extent it invites confidence.

The one clearly demonstrable feature of the single specimen of Mylostoma studied by Dean is that the right and left halves of the palatal dentition have become separated; and that, although the components of either half remain in association, they are dissimilarly oriented. This state of affairs permits of three possible explanations, which may be stated as follows: —

1. The two right-hand palatal plates have preserved their natural orientation with respect to each other, and the two left-hand plates alone have become disarranged.

2. The two left-hand palatal plates retain their natural orientation with respect to each other, and the two right-hand plates have become disarranged.

3. The components of both halves of the palatal dentition have become turned about, so that none of them any longer occupy their original position with respect to one another.

Circumstantial evidence is our only resource for determining which one of these conclusions is correct. A strong point in favor of the first is the neat adjustment between the contact edges of the plates, which are preserved in direct apposition. At the same time, the close fit observed between the two nearly straight edges cannot be regarded as really decisive proof, owing to the possibility of its being the result of chance. The two right-hand palatal plates may or may not be retained in natural position; the only test that can be absolutely relied on for determining their arrangement, the real *experimentum crucis*, consists in bringing the functional surfaces of the two upper dental plates into harmonious adjustment with the mandibular, so that a number of diverse features of both upper and lower dental plates shall stand in reciprocal relations. When tubercles are found to fit into grooves or pits, eminences into depressions, and marks of wear to coin-

cide at all points we have evidently found the true arrangement; since only in this manner could the parts have interacted during life. Application of this test to the single individual of Mylostoma we are considering, and also to an extended series of detached plates, shows that Dean's reconstruction fails to explain all the facts, and only explains some of them by positing anomalous, and *pro tanto* improbable conditions. In a word, the arrangement is unable to satisfy the test of totality. It is, therefore, inadequate, and the initial assumption upon which it is based must be regarded as erroneous.

The principal objections to Dean's reconstruction may be thus summarized: —

1. The proposed arrangement necessitates the assumption of jaw-movements in Arthrodires which are unparalleled amongst Chordates.

2. No close analogy is suggested by this arrangement with the dentition of related forms.

3. Some conspicuous indications of wear, the position of which is constant in all plates thus far brought to light, are wholly unaccounted for by this arrangement.

4. According to this arrangement, the marginal contours of upper and lower dental plates do not coincide. A considerable portion of the oral surface of all the plates is left uncovered when the jaws are closed, even including areas which show indications of wear.

5. One of the two palatal plates found lying in apposition in the nearly complete example of Mylostoma (the one called "premaxillary" by Dean) is observed to present a worn surface immediately adjoining the contact margin with the so-called "maxillary" element. The latter, however, is unworn along the contact margin, but is raised there into a prominent ridge. Supposing these plates to have been naturally in contact, they must needs exhibit similar evidence of attrition along their common margin; since they do not, they must have been arranged in some other manner.

6. The only strictly linear margins of any of the plates are not in contact with each other, nor are the members of either pair in direct apposition along the median line.

Eastman's Interpretation. — The arrangement proposed by the present writer was first established upon the evidence of detached plates, which were fitted together conformably to the marginal contours of upper and lower dentition, and in such manner as to account at all points for reciprocal marks of wear. Its efficiency was afterwards tested by applying the same arrangement to the single example of Mylostoma

studied by Dean. The two left-hand palatal plates being removable from the specimen, they were rearranged in the prescribed manner, and their oral surfaces fitted against the mandibular dental plate. The experiment was also repeated with the aid of plaster casts of the two right-hand palatal plates, which were not removable, and in both cases the new arrangement was found competent to explain all the facts in thoroughly satisfactory manner. Its effectiveness will be readily understood from inspection of Figure *C*, drawn from the original specimens, and from the following discussion of details.

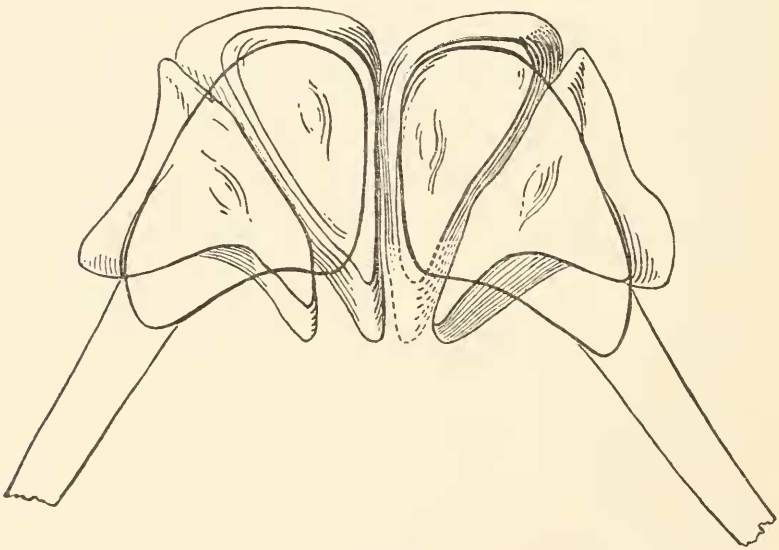

FIGURE *C*.

Proposed reconstruction of Mylostomid dentition, based upon the originals shown in preceding text-figures. × ½.

We have already stated that the juxtaposition of dental plates in the nearly complete example of Mylostoma is such as to admit of three possible conclusions, only one of which can be true. The new arrangement proceeds to test, and afterwards to affirm the correctness of the second of these conclusions, which are here restated for sake of clearness.

1. The two right-hand palatal plates are retained in their natural position with respect to each other. (Disproved.)

2. The two left-hand palatal plates are naturally oriented with re-

spect to each other, and the two right-hand plates have become disarranged.

3. None of the palatal plates retain their natural position with respect to one another.

By orienting the two right-hand plates in corresponding fashion to the two left-hand, and then approximating the disjoined halves of the dentition, a symmetrical pattern is formed, such as is shown in Figure *C*, and repeated in Plate 1. An obvious feature of this arrangement is that the only elongate linear margin of any of the plates is directed parallel to the median line, and it is along this line that the paired elements having a single straight margin are mutually in contact. The evidence of co-adaptation presented in this respect is sufficiently striking, and it will be at once recalled that analogous conditions are found in various types of Dipnoan dentition.

We have now to apply the most crucial test open to us with the means at our command. It consists in bringing the functional surfaces of mandibular and palatal plates together and observing the extent of their mutual correspondence. Immediately this is done it becomes patent that a close coincidence exists between the contour lines of upper and lower dentition; the jaw-parts fit together as accurately as may be when the mouth is closed, and their impact is exactly such as is capable of producing the observed marks of wear. The triturating areas that were left uncovered in the preceding restoration (Fig. *B*) are now brought into much closer adjustment above and below, the contrast presented by Figure *C* in this respect being self-evident. It thus appears that the fourth in the list of objections to Dean's arrangement (*v.* p. 217) is inapplicable in the present instance.

Amongst other constant features of the anterior pair of palatal plates are to be noted the following: The linear inner (ental) margin is elevated into a distinct ridge, which increases in height and breadth in the vicinity of the antero-internal angle of the plate, where it shows evidence of attrition. The marks of wear extend not only along the side of this ridge, but also over the concave surface of the plate immediately adjacent to it. The summit of the elongate, mesially placed tubercle is worn, and the sunken area in advance of this, extending as far as the antero-external angle is the most conspicuously worn of all. This concavity is particularly well displayed in the detached specimens figured by the writer in Bulletin Mus. Comp. Zoöl., 50, no. 1, Plate 1, Figures 2, 3. Now, the significance of all these features becomes apparent when the functional surface of the plate in question is applied

against the mandibular in the manner already described. On bringing the two surfaces together, all marks of wear observable in the anterior palatal plate are seen to coincide with similar worn areas of the opposing plate, thus fully disclosing their mutual relations.

The ental margin of the mandibular plate fits just within and against the side of the ental ridge of the palatal plate, and closes against the thickest and highest portion of the ridge near the antero-internal angle, where both plates are deeply worn. The ectal rim of the mandible fits accurately into the broad and deeply worn concavity of the palatal plate, the surface of the one being a faithful replica of the other, and the relations between them being comparable to those of a die-stamp. The extremely prominent bifid eminence which rises midway the length of the mandibular plate along its ental margin functions within the depressed posterior surface of the palatal, and the longitudinal cleft by which the eminence is divided embraces the elongate, mesially placed, and longitudinally directed tubercle of the palatal plate, whose summit fits into a shallow groove of the mandibular plate. Thus an interrelationship between all the parts is demonstrable, which must faithfully indicate their natural arrangement, since no other is capable of producing the observed effects. Having ascertained the relations of the anterior palatal plates, it is an easy task to bring the hinder one into adjustment with it and with the remaining portion of the lower dentition.

The posterior palatal plate may be described as approximately cordiform, or subtriangular. Not more than two of its borders are straight or slightly concave, the third being profoundly indented, and for that reason incapable of direct contact with the preceding element. The contact margin must therefore have been formed by one or the other of the nearly linear sides, and by experimenting with them in connection with the two plates whose relations have already been determined, it is readily perceived which one of these sides permits of harmonious adjustment. The pointed anterior extremity of the plate we are now considering adapts itself regularly to the outer contour line of the mandible; its worn centrally placed tubercle fits into a depression of the lower plate; and its marginally situated tubercle closes just back of the elevated prominence of the mandibular plate, playing into a declivity that occurs on the inner face of the latter. The surface irregularities of both plates, together with all their indications of wear, are thus fully accounted for by this arrangement. Noteworthy also is the fact that precisely similar relations obtain in Dinomylostoma, where the orien-

tation of the posterior palatal plates is determined with absolute accuracy. Another point confirmatory of the new arrangement is that in the nearly complete example of Mylostoma (Fig. *A*), the posterior pair of palatal plates occurs symmetrically oriented with reference to the median line. From this it is evident that the only one of the four palatal plates whose position has been disturbed, aside from lateral displacement, is the right anterior.

The present reconstruction of the palatal dentition of Mylostoma thus provides a consistent explanation of all observed facts, and is at variance with none of them. It is free from theoretical objections, is in harmony with analogy, both with Dinichthys and Ceratodonts, and is applicable to all specimens thus far discovered, whether found in the detached or associated condition. Its correctness may therefore be regarded as definitely proved. Up to the present point the discussion has been purposely restricted to the palatal and mandibular dental plates.

Concerning those structures interpreted by Newberry as "premandibular," and by the present writer in earlier papers as "vomerine" teeth, it is now necessary to speak more particularly. I purpose showing that the three known specimens which have received this designation do not belong to the type species of Mylostoma, but to a smaller, very distinct form, presently to be described under the name *M. newberryi*. Moreover, the specimens in question are no longer interpreted as vomerine, but as mandibular plates which have become accidentally dissociated from their supporting splenials, or from the greater part of these bones. The presence of vomerine teeth in Mylostoma is therefore not yet demonstrable by any positive evidence that has come to light, although their potential occurrence is to be inferred from analogy with Dinomylostoma and Coccosteans generally.

Indications of a New Species of Mylostoma. — As already stated, Newberry was of the opinion that the lower dentition of Mylostoma consisted of at least two pairs of dental plates, mandibular and "premandibular," opposed to which in the upper jaw was a "tesselated pavement consisting of many pairs of plates." Bashford Dean was enabled to show that the upper pavement dentition was made up of two pairs of plates only, against which functioned the single mandibular pair. In the nearly complete example of *M. variabile* studied by this author no trace was observed of yet another fourth pair of dental structures, corresponding to those named premandibular by Newberry, and vomerine by the present writer. The originals of Newberry's figures do not enter

into Dean's restoration of the Mylostomid dentition, nor is their existence mentioned. As a matter of fact, the actual specimens had been lost sight of for many years, and in the absence of satisfactory illustrations it was difficult to hazard a conjecture as to their nature. Without having studied the originals, no one could have concluded that they had suffered such injury as to obscure their real nature, nor could any good reason be assigned for excluding them from association with the type species of Mylostoma.

By a fortunate chance the original pair of Newberry's so-called "premandibular teeth" have been preserved intact in the Museum of Oberlin College, where they were overlooked until recently. Being recognized by Dr. Hussakof, after searching various collections, they were loaned to him and subsequently placed in the hands of the present writer for purpose of further study and description. Grateful acknowledgments are hereby rendered to the writer's colleagues in New York and Oberlin for having thus provided an opportunity for the following observations.

Comparison of the original pair of dental elements figured in Plate 16, Figure 4, of Newberry's Monograph with the lower dental plates of Mylostoma, especially those of the single individual of *M. variabile* described by Dean, leaves no room for doubt that they are of similar nature. We have not to do with integral paired structures representing a distinct element, but with a fractured pair of mandibles belonging to a new species of Mylostoma. The inferior aspect in particular of Newberry's originals displays the usual conformation of grooves, ridges, and hollows with which we are familiar in Mylostomid mandibles. One of these grooves is extremely characteristic of the Arthrodiran type of mandible, always occupying the same position, and from its similarity to a corresponding groove in modern Dipneumoni, has been interpreted as serving to lodge remnants of the Meckelian cartilage. The line of fracture along which the posterior shaft of the splenial has been broken off is irregular, even ragged in places, and so obviously the result of injury that it is surprising Newberry should not have noticed it. Curiously enough, in the case of the solitary known specimen agreeing with the typical pair, the same which we have previously called "vomerine," signs of injury are scarcely to be perceived, and would seem to have become almost wholly obliterated by post-mortem attrition. Yet it follows by implication that the Cambridge specimen has likewise suffered the loss of the supporting splenial.

There can be no question that the Oberlin pair of mandibular plates

belonged to a single individual. This is shown by their almost perfect symmetry, similar texture, equal extent of wear, and especially by the evidence of co-adaptation along their linear inner margins, where they were in contact along the median line. The indications of a rigid cartilaginous union at the symphysis are of an even more positive character than in Ptyctodonts, for in these plates the contact line is more extended, and the adjustment along the vertical inner face more accurate. On bringing these surfaces into adjustment, it is easy to see from the alignment of the splenial portions that the angle subtended by the mandibular rami must have been very narrow. The pointed form of the plates in front leads also to the conclusion that the head was sharp-snouted, slender, and elongate, indicating a creature adapted for rapid motion, and possibly one having an eel-like form of body.

A marked feature of the mandibular plates as compared with those of the type species of Mylostoma is the narrowness of their functional surface, with tapering forward extremities, a character by which the new form is readily distinguished from all other Mylostomids. The triturating surface is moderately convex, and displays the usual tubercle along the inner margin, although this is less elevated than in other species, and is more distinctly separated from the posterior portion of the plate by a deep sinus. This is the concavity referred to in Newberry's description, where it is suggested that the posterior margin of the "premandibular" plates is "obliquely notched, apparently to receive the obtuse points of the larger teeth." In addition to the main eminence along the inner margin, faint indications are visible in the Cambridge specimen of two or three rows of smaller tubercles, radiating outwards in a manner strikingly suggestive of Ctenodipterine teeth. Similar markings were no doubt present in the Oberlin examples as well, but have become obliterated by wear. Their larger size and more worn condition suggest that they pertained to an older individual than that represented by the Cambridge specimen (M. C. Z., Cat. no. 1439). The form of all three strongly recalls Ctenodipterine conditions, and it is probable that the resemblance extended to the upper dental plates as well. They were no doubt attenuated anteriorly in corresponding fashion with the mandibular plates, their oral surfaces were regularly concave and very possibly tuberculated, and it would not be at all surprising if the two pairs of upper dental plates common to other Mylostomids were in this species fused into one. This would give rise to a compact triangular-shaped plate, closely paralleling those of typical Dipnoans.

The new species may appropriately be named in honor of the memory

of Professor Newberry. Its principal characters are summed up in the following definition.

Mylostoma newberryi, sp. nov.

Fig. D.

1889. *Mylostoma variabilis* Newberry, Mon. U. S. Geol. Surv. **16**, p. 165, plate **16**, fig. 4 (*non* figs. 1–3).

1906. *Mylostoma variabile* Eastman, Bull. Mus. Com. Zoöl., **50**, p. 22, plate **1**, fig. 7 (*non* figs. 1–5, 8–9).

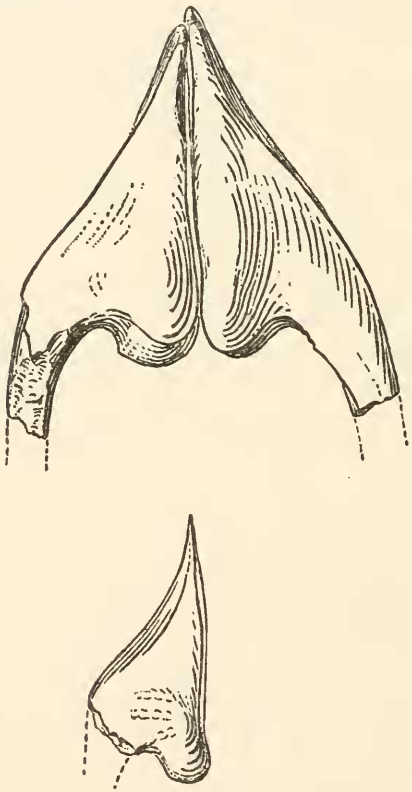

FIGURE *D.*

Mylostoma newberryi, sp. nov. Cleveland shale; near Sheffield, Ohio. *Above*, the original pair of Newberry's so-called "premandibular teeth," here interpreted as mandibular (Oberlin Museum Cat. 1302). *Below*, a smaller left mandibular plate (Museum of Comparative Zoölogy Cat. 1439). × ½.

An imperfectly known species, established upon the evidence of mandibular dental plates which have become accidentally dissociated from their supporting

splenials. Functional surface moderately convex, of narrow, subtriangular outline, tapering and acutely pointed in front, with elongated linear inner margin showing distinct evidence of coadaptation along the median line, and notched posteriorly in the vicinity of the single rounded eminence into which the ridge along the inner margin gradually rises. Adjacent to this eminence are to be seen in unworn specimens a few rows of small rounded tubercles, radiating outwards, but tending to become obliterated by use, and the larger eminence tending also to become worn down. Oral surface sloping gradually towards the bevelled external margin, but falling precipitately along the inner and posterior borders. Under surface displaying the characteristic ridges and depressions of Mylostomids, besides the usual groove for lodging remnants of the Meckelian cartilage. Jaw-angle acute, indicating a very slender, possibly anguilliform body.

Homologies of Mylostomid Dental Plates. — Throughout the foregoing section we have employed the term "palatal plates" merely as a convenient designation for the paired elements forming the upper pavement dentition of Mylostomids, without having precisely indicated their relations to other forms of crushing dentition. Newberry may possibly have assumed, although his writings nowhere indicate it, that these plates are homologous with the dental elements in the upper jaw of Dinichthys and other Arthrodires. He did, however, point out their obvious resemblance to the single pair of upper dental plates in Ceratodonts, his remarks on this subject being as follows :[1]

"The resemblance of the teeth which I have supposed formed the roof of the mouth to those of *Ceratodus* will strike any one who examines them, and no closer analogy suggests itself in the whole range of ichthyic dentition. There is, however, this marked difference, that while in *Ceratodus* there is only one pair of dentary [*i. e.*, dental] plates borne on the palato-pterygoid bones, in *Mylostoma* there were certainly several pairs of pavement teeth in the roof of the mouth. The spatulate bones which form the supports of the principal dental plates of the lower jaw evidently represent the thin, flattened, smooth, and once buried posterior end of the dentary bone [= splenial] in all of the Dinichthidae."

The earliest effort to trace homologies between the dentition of Mylostoma and Dinichthys is that of Bashford Dean, in 1901. Relying upon analogy with Dinichthys, he assumed that the upper dentition of Mylostoma must have been limited to two pairs of plates only; and finding that number to be present in the nearly complete example of *M. variabile* studied by him, he concluded that one of these pairs must correspond to the so-called "premaxillary" element, and the other to the so-called "maxillary" or "shear-tooth" of Dinichthys. Apparently the possibility did not occur to him that the two pairs of

[1] *Loc. cit.* (1889), p. 162.

tritoral plates in Mylostoma might together be equivalent to the single "maxillary" element, as it is commonly called in Dinichthys, and that a third pair of upper dental plates representing the "premaxillaries" were either actually or potentially present in Mylostoma. At all events greater weight was placed upon assumed numerical correspondence of dental plates in the two genera than upon morphological equivalence, for it is impossible to recognize the least similitude in form between the usual Arthrodiran "premaxillary" and either of the tabular crushing plates of Mylostoma. Denying that Arthrodires belong to Pisces proper, and that they have gill-arch jaws, he holds that their dental apparatus is non-homologous with that of all other fishes.

According to the present writer's interpretation, the two pairs of Mylostomid palatal plates are together equivalent to the single pair of "maxillary" elements in the Coccosteid type of dentition, this latter being regarded merely as a modification of the Mylostomid, adapted for cutting instead of crushing. That the upper dentition of Mylostoma consists in all of three pairs of plates, the foremost of which is the precise morphological equivalent of the so-called "premaxillary" pair in Dinichthys, is to be inferred not only from analogy with Dinomylostoma, in which this number has been definitely proved to obtain,[1] but from the remarkable constancy of form displayed by the more forwardly placed element in all Arthrodiran genera where it is known to occur. Unacquainted though we be with actual specimens, the existence of vomerine teeth in Mylostoma, real or potential, is an assured fact.

It follows from the point of view just stated that the Mylostomid and Dinichthyid types of dentition are reducible to a common plan, and this plan is further seen to be identical with that found in Dipnoans. The one element which by virtue of its function retains a constant form among Coccosteans generally, and in at least one genus of Mylostomids, is that commonly known as the "premaxillary," in reality the *vomerine* tooth; and the palatal plates (or more properly the palato-pterygoids) of the more primitive Mylostomid type are seen to have become fused, turned upright, and sharpened into a cutting edge along their functional margin in the more specialized Dinichthyid type.

[1] The recently published suggestion on the part of Dr. Hussakof (Mem. Amer. Mus. Nat. Hist. 1906, **9**, p. 119) that the type of *Dinomylostoma beecheri* includes portions of more than one individual, all embedded in a single block of shale, is now abandoned by that writer as the result of further study of the original material. This statement is made here with Dr. Hussakof's consent.

The Mylostomid is properly regarded as the more primitive type of dentition on account of its obvious agreement with the Ceratodont, a fact previously noted by Newberry. And indeed, as he rightly observed, their resemblance is such as "will strike any one who examines them, and no closer analogy suggests itself in the whole range of ichthyic dentition." The combined evidence of dental, cranial, and most of the skeletal characters (the only marked exception being that of dermal armoring) furnishes wellnigh irresistible proof of the Dipnoan affinities of Arthrodires. A close parallel exists between the dentition of Mylostoma and Ceratodonts on the one hand, and Dinichthys and Protopterus on the other. The coincidence ceases to be remarkable when it is understood that other facts as well point to a common origin for Ceratodonts and Arthrodires. Very interesting also is Semon's observation that in the young of Neoceratodus the upper dental plates are at first divided into two pairs, as in Mylostomids, these afterwards combining into a single pair of palato-pterygoids.[1]

Adopting the view that the Arthrodiran type of dentition is strictly homologous with the Dipnoan, it is desirable to employ uniform designations for the dental parts. The tooth usually called "premaxillary" in the former group is therefore to be identified with the *vomerine* of typical Dipnoans, and the one or two succeeding pairs of "maxillaries" as the case may be, with the *palato-pterygoid* dental plates. The latter may be supposed to have been supported by the palato-pterygoid cartilage in Mylostoma precisely in the same manner as in Ceratodonts and Ctenodipterines. Their homologues in Dinichthys were no doubt situated well within the interior of the headshield, as we have a right to expect, at least, from analogy with Mylostoma. Some device is evidently required, owing to their large size, to take up the strains due to impact against the powerful lower dentition, and this we find actually provided for by the massive ridges developed on the under side of the headshield, whose position, direction, and inferred function suggest comparison with similar ridges in Neoceratodus.

Conclusions. — The consequences depending upon Dean's reconstruction of the Mylostomid dentition are as follows: The complete upper dentition of Mylostoma consists of two pairs of tritoral plates only, one of which is the functional, but not the morphological equivalent of the

[1] Consult in this connection the recently published conclusions of Prof. J. Graham Kerr on the genetic affinities of lower Gnathostomata, in his paper entitled Embryology of certain of the lower Fishes, and its bearing upon Vertebrate Morphology. Proc. Roy. Phys. Soc. Edinb. 1906, **16**, pp. 191-215.

"premaxillary" teeth in Dinichthys, and the other of the so-called "maxillary" or "shear-teeth." The hypothesis of an additional paired element in advance of these two, itself representing the "premaxillary" in Dinichthys, is not considered in the case of Mylostoma, and rejected in the case of Dinomylostoma. The tritoral plates are arranged in such manner that the mandibles cannot close against them directly so as to produce the observed marks of contact without operating by rotary movements, and without being capable of approximation and separation at their anterior extremities, — conditions which are unparalleled among Chordates. All the jaw-parts are regarded as of purely dermal origin, and therefore non-homologous with those of ordinary fishes. Their alleged structural differences, and assumed functional differences, make it necessary to exclude Arthrodires from fishes proper.

The consequences depending upon the newer reconstruction of the same materials are that all known Dinichthyids and at least one Mylostomid have a similar form of "premaxillary," which is the exact homologue of the vomerine teeth in Dipnoans, and that the succeeding pair or pairs (when two are present) of trenchant or crushing plates are homologous with the palato-pterygoid dental plates of typical Dipneusti. The jaws operate in the usual manner, are of the normal gill-arch type, and exhibit precisely the same conformation as those belonging to autostylic fishes. The combined evidence of the majority of characters of Arthrodires proves that they are specialized Dipnoans.